Ka-Band Reflectarray for Interferometric SAR Altimeter

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***Abstract*—This paper describes a large dual-beam, dual polarized Ka-Band reflectarray antenna prototype which was developed to demonstrate that key requirements of a space borne interferometric radar altimeter are achievable. The antenna consists of a 2.5 x 0.26 m aperture comprised of a rectangular grid of square patch printed circuit elements. The 2.6 m focal length offset-fed reflector is illuminated by a waveguide slot array feed focused in the nearfield. Measured results show good agreement with gain and radiation pattern predictions and demonstrates >50% aperture efficiency.**

I. Introduction and Background

The proposed Surface Water Ocean Topography (SWOT) mission, currently in formulation by NASA and CNES, would employ a Ka-band Radar Interferometer (KaRIn) system to characterize ocean mesoscale and sub-mesoscale circulation at spatial resolutions of 10 km and provide a global inventory of all terrestrial water bodies whose surface area exceeds $(250\text{m})^2$ (lakes, reservoirs, wetlands) and rivers whose width exceeds 50-100m. The interferometer is formed by a pair of 5m x 0.26m reflectarray antennas (Figure 1) separated by a 10 m baseline. Each antenna creates two beams, one V-pol and one H-pol, which illuminate the two 10-70 km swaths. These antennas are a key technology driver for the KaRIn instrument.

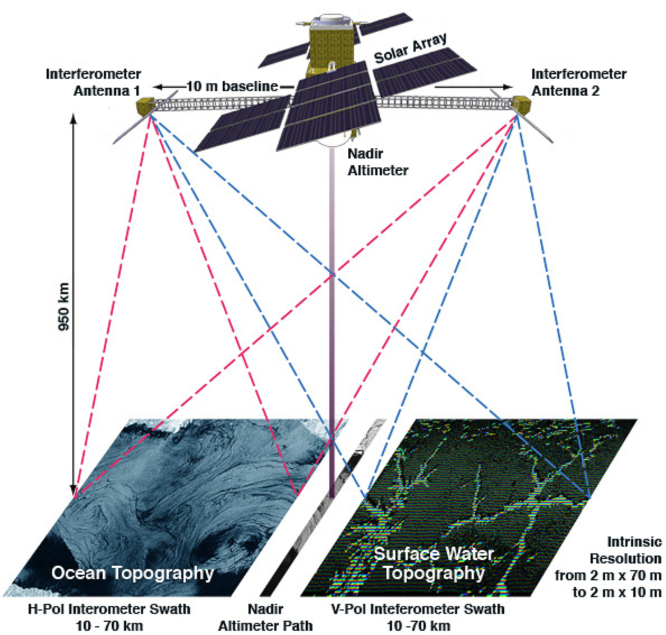

Figure 1. SWOT interferometric SAR system concept.

The key system requirements for these antennas are gain, phase stability and accurate characterization of antenna performance on orbit. Characterization of on-orbit performance is achieved through a multi-physics simulation that uses a model of spacecraft solar illumination in conjunction with thermal and structural analysis to determine antenna temperatures and deformation, which is then input into the antenna RF analysis program. The resulting antenna patterns are then used to perform interferometric system simulations. Consequently, accuracy of the antenna RF analysis is of critical importance for system verification and validation.

II. Breadboard Antenna Design

A breadboard reflectarray antenna was built to verify that key performance requirements are achievable and also to evaluate antenna RF modeling accuracy. Cost constraints and test facility limitations precluded breadboard testing of the full size 5m aperture antenna configuration. Instead, the design was scaled geometrically 2:1 in azimuth, resulting in a 2.5m aperture, while retaining the full elevation aperture size of 0.26m as illustrated in Figure 2. The scaled focal length of 2.3m is half that of the planned full size antenna. The aperture is comprised of five 50 x 26 cm panels, which is a convenient size for fabrication using standard printed circuit etch methods. The aperture and feed are mounted on an aluminum support structure as illustrated in Figure 3 and includes tooling balls for precision optical alignment of the panels to within ±4 mils (maximum deflection from best fit plane)

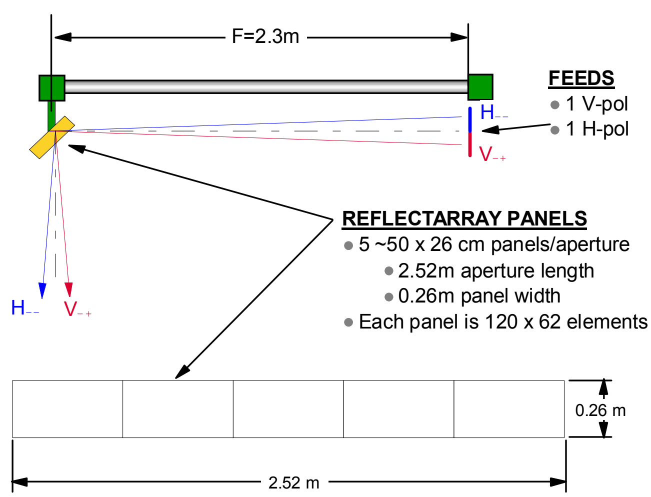

Figure 2 SWOT Half-Size BB Antenna Configuration

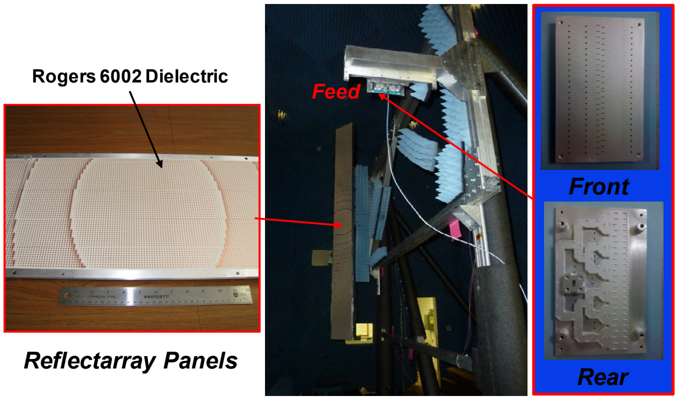

Figure 3 Photographs of Reflectarray antenna showing closeup view of panels (left) and slot array feed (right).

The reflectarray electrical design was carried out using the Floquet mode unit cell method [1] which employs a Moment Method code with a 32 mode entire domain basis function set [2]. Each reflectarray panel has 120 x 62 square printed circuit patch elements. Two dielectric substrate designs were tested: (1) Rogers 4003 LoPro, 0.3226mm (12.7mil) thick, ε_r = 3.58 and (2) Rogers 6002, 0.381mm (15mil) thick, ε_r = 2.94. The Rogers material is bonded to a precision aluminum support, and the 5 panels are mounted to precision tooling plate which is shimmed to provide precise alignment. The V-pol feed is a uniformly illuminated 24x2 element rectangular waveguide slot array with a cylindrical phase front at the aperture to focus the beam in the near field at 2.3m. A feed architecture similar to [3] is employed, wherein each two element row is a resonant longitudinal shunt slot design fed by a corporate feed (Fig 3). The feed is constructed as an aluminum dip brazed hog out.

III. Performance Test Summary

The BB reflectarray was tested using a 15 x 30 ft Nearfield Systems, Inc. planar nearfield scanner in the JPL Mesa Antenna Test facility (Fig 3). Upon installation of the breadboard antenna in the test facility, a laser tracker was used to determine relative position of the feed, reflectarray surface and antenna range coordinate system. This metrology data was subsequently used to calculate coordinate transformations which present the measured antenna patterns in terms of the antenna calculation coordinate system. Table 1 shows the calculated vs. measured beamwidth for the RO4003 design, center beam position at 35.75 GHz. Beam pointing accuracy for this configuration is $\Delta\theta_x$=0.00129°=0.0064 BW (azimuth) and $\Delta\theta_y$=0.01013°=0.0038 BW (elevation). These results show very good prediction accuracy.

Table 1 Calculated vs. Measured Beamwidth (RO 4003)

	CALC (deg)	MEAS (deg)	Delta (deg)	Delta (BW)
EL	2.6368	2.6589	0.0221	0.0083
AZ	0.2017	0.2014	0.0003	0.0015

Beam scanning is accomplished by displacing the feed from the focal point as described in [4]. Radiation patterns were measured for the nominal beam (feed located at the focal point) and with the feed offset to scan the beam ±2.8° from boresight. Figures 4 and 5 show the measured vs. calculated elevation and azimuth patterns at the center frequency 35.75 GHz for the RO 4003 design, which shows good agreement between calculated and measured results.

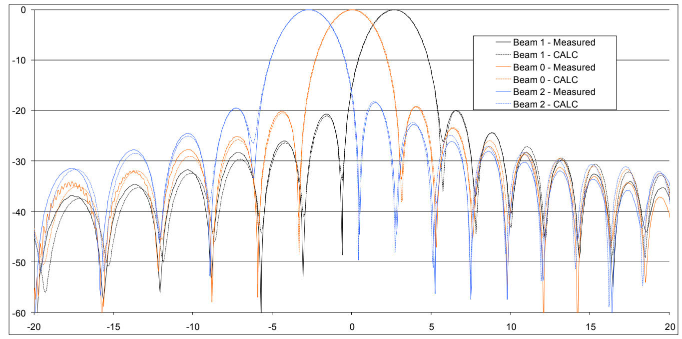

Figure 4 Measured vs. calculated elevation patterns.

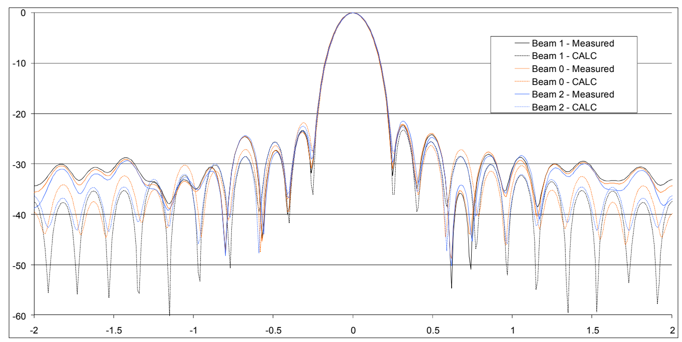

Figure 5 Measured vs. calculated azimuth patterns

IV. Acknowledgement

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V. References

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